

RD-29,605-4 is a Continuation-in-Part of  
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## WEATHERABLE MULTILAYER ARTICLES AND METHOD FOR THEIR PREPARATION

### CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of copending U.S. application Serial No. 10/371,754, filed February 21, 2003, which is a continuation-in-part of copending U.S. application Serial No. 10/012,136, filed November 30, 2001, which are incorporated herein by reference.

### BACKGROUND OF THE INVENTION

[0002] The present invention relates to weatherable multilayer resinous articles and their preparation. More particularly, it relates to multilayer articles comprising a protective block copolyestercarbonate coating, a second layer comprising a polymer comprising carbonate structural units, a substrate, and at least one adhesive layer between the second layer and the substrate.

[0003] Various resinous articles have a problem of long term color instability. This causes yellowing of the polymer resin, which in some embodiments detracts from its transparency and attractiveness. Loss of gloss can also be an undesirable long term phenomenon.

[0004] Yellowing of polymers is often caused by the action of ultraviolet radiation, which is why such yellowing is frequently designated "photoyellowing". Numerous means for suppressing photoyellowing have been employed and proposed. Many of these involve incorporation in the polymer of ultraviolet absorbing compounds (UVA's). For the most part, UVA's are low molecular weight compounds and they must be employed at relatively low levels, typically up to 1% by weight, to avoid degradation of the physical properties of the polymer such as impact strength and high temperature properties as reflected in heat distortion temperature. Such levels may be inadequate to afford sufficient protection.

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[0005] One way of protecting a resinous article against photoyellowing and loss of gloss is to apply a coating of a weatherable second polymer, the term "weatherable" as used herein signifying resistance to such phenomena. Weatherable polymers suitable for this purpose include resorcinol isophthalate/terephthalate copolyarylates. This is the subject of Cohen et al., J. Poly. Sci., Part A-1, 9, 3263-3299 (1971), and certain related U.S. Patents of Monsanto Company including Nos. 3,444,129, 3,460,961, 3,492,261 and 3,503,779. Commonly owned, published application WO 00-61664 is directed to weatherable multilayer articles with coating layers comprising structural units derived from a 1,3-dihydroxybenzene organodicarboxylate. Commonly owned U.S. Patent No. 6,306,507 is directed to weatherable multilayer articles with coating layers comprising at least one coating layer thereon, said coating layer comprising a thermally stable polymer comprising resorcinol arylate polyester chain members substantially free of anhydride linkages linking at least two mers of the polymer chain, prepared by an interfacial method.

[0006] Japanese Kokai 1/199,841 discloses articles having a substrate layer comprising at least 90 mole percent poly(ethylene terephthalate) and a gas barrier coating layer which is a polyester of resorcinol and isophthalic acid, optionally with copolyester units derived from another dicarboxylic acid such as terephthalic acid, naphthalenedicarboxylic acid or various other specifically named dicarboxylic acids. The disclosed articles may be prepared by a series of operations including co-injection molding which are essentially performed entirely in the melt, thereby overcoming the aforementioned deficiencies of solution coating. However, the only types of articles disclosed are bottles, which are produced from a co-injection molded parison by subsequent blow molding. Larger articles intended for outdoor use, such as external automobile body parts, are not disclosed and no method for their production is suggested, nor are articles in which the substrate layer is anything other than poly(ethylene terephthalate).

[0007] It remains of interest, therefore, to develop a method for preparing weatherable multilayer articles which are capable of use for such varied purposes as body parts for outdoor vehicles and devices such as automobiles, and which exhibit adequate adhesion between the various layers.

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## BRIEF DESCRIPTION OF THE INVENTION

[0008] The present inventors have discovered multilayer articles with coating layers which provide protection from weathering for underlying layers, and which exhibit excellent adhesion between the various layers. In one of its embodiments the present invention comprises a multilayer article comprising (i) a coating layer comprising a block copolyestercarbonate comprising structural units derived from at least one 1,3-dihydroxybenzene and at least one aromatic dicarboxylic acid, (ii) a second layer comprising a polymer comprising carbonate structural units, (iii) an adhesive layer comprising a polyurethane, and (iv) a substrate layer comprising at least one material selected from the group consisting of a thermoplastic resin, a cured thermoset resin, a metal, a ceramic, a glass, and a cellulosic material, wherein the coating layer is in contiguous contact with the second layer, and the adhesive layer is in contiguous contact with the second layer and the substrate layer. In another of its embodiments the present invention comprises a method for preparing said multilayer article.

[0009] Various other features, aspects, and advantages of the present invention will become more apparent with reference to the following description and appended claims.

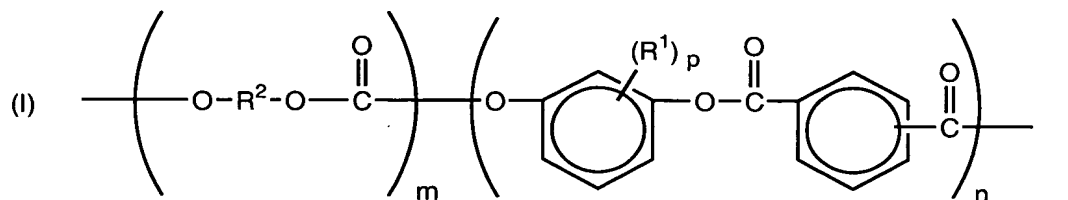
## DETAILED DESCRIPTION OF THE INVENTION

[0010] In the following specification and the claims which follow, reference will be made to a number of terms which shall be defined to have the following meanings. The singular forms "a", "an" and "the" include plural referents unless the context clearly dictates otherwise. "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not. As used herein the term "layer" is used interchangeably with the terms "film" and "sheet". The terms "adhesive layer" and "tie layer" are used interchangeably.

[0011] The copolyestercarbonate film in the multilayer articles of the present invention comprises at least one block copolyestercarbonate comprising alternating carbonate and arylate blocks. Such block copolyestercarbonates include polymers

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comprising 1,3-dihydroxybenzene structural units and aromatic dicarboxylic acid structural units of the Formula (I):



wherein each  $R^1$  is independently halogen or  $C_{1-12}$  alkyl,  $p$  is 0-3, each  $R^2$  is independently a divalent organic radical,  $m$  is at least 1 and  $n$  is at least about 4. In some embodiments  $n$  is at least about 10, in other embodiments at least about 20 and in still other embodiments about 30-150. In some embodiments  $m$  is at least about 3, in other embodiments at least about 10 and in still other embodiments about 20-200. In other embodiments  $m$  is between about 20 and 50. Within the context of the invention "alternating carbonate and aryate blocks" means that the copolyestercarbonates comprise at least one carbonate block and at least one aryate block. In particular embodiments block copolyestercarbonates comprise at least one aryate block and at least two carbonate blocks. In another particular embodiment block copolyestercarbonates comprise an A-B-A architecture with at least one aryate block ("B") and at least two carbonate blocks ("A").

[0012] The aryate blocks contain structural units comprising 1,3-dihydroxybenzene moieties which may be unsubstituted or substituted. Alkyl substituents, if present, are often straight-chain or branched alkyl groups, and are most often located in the ortho position to both oxygen atoms although other ring locations are contemplated. Suitable  $C_{1-12}$  alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, isopropyl, butyl, iso-butyl, t-butyl, nonyl, decyl, and aryl-substituted alkyl, including benzyl. In some embodiments any alkyl substituent is methyl. Suitable halogen substituents include bromo, chloro, and fluoro. 1,3-Dihydroxybenzene moieties containing a mixture of alkyl and halogen substituents are also suitable. The value for  $p$  may be in one embodiment 0-3, in another embodiment 0-2, and in still another embodiment 0-1. In one embodiment a 1,3-dihydroxybenzene moiety is 2-methylresorcinol. In many embodiments a 1,3-dihydroxybenzene moiety is

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unsubstituted resorcinol in which p is zero. Polymers containing mixtures of 1,3-dihydroxybenzene moieties, such as a mixture of unsubstituted resorcinol with 2-methylresorcinol are also contemplated.

**[0013]** In the arylate structural units said 1,3-dihydroxybenzene moieties are bound to aromatic dicarboxylic acid moieties which may be monocyclic moieties, such as isophthalate or terephthalate or their halogen-substituted derivatives; or polycyclic moieties, illustrative examples of which include biphenyl dicarboxylate, diphenylether dicarboxylate, diphenylsulfone dicarboxylate, diphenylketone dicarboxylate, diphenylsulfide dicarboxylate, or naphthalenedicarboxylate. In some embodiments polycyclic moieties comprise naphthalene-2,6-dicarboxylate; or mixtures of monocyclic and/or polycyclic aromatic dicarboxylates. In many embodiments the aromatic dicarboxylic acid moieties are isophthalate and/or terephthalate. Either or both of said moieties may be present. In one embodiment both are present in a molar ratio of isophthalate to terephthalate in the range of about 0.20-5.0:1, while in another embodiment both are present in a molar ratio of isophthalate to terephthalate in the range of about 0.25-4.0:1. When the isophthalate to terephthalate ratio is greater than about 4.0:1, then unacceptable levels of cyclic oligomer may form in some embodiments. When the isophthalate to terephthalate ratio is less than about 0.25:1, then unacceptable levels of insoluble polymer may form in some other embodiments. In some embodiments the molar ratio of isophthalate to terephthalate is about 0.40-2.5:1, and in other embodiments about 0.67-1.5:1.

**[0014]** In various embodiments the arylate block segments in the copolyestercarbonates are substantially free of anhydride linkages linking at least two mers of the polymer chain. Substantially free of anhydride linkages in the present context means that the copolyestercarbonates show decrease in molecular weight in some embodiments of less than 10% and in other embodiments of less than 5% upon heating said copolyestercarbonates at a temperature of about 280-290°C for five minutes.

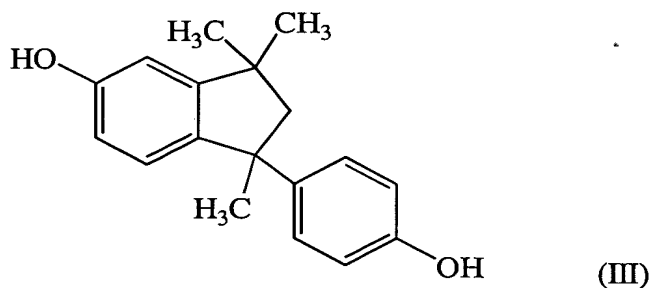
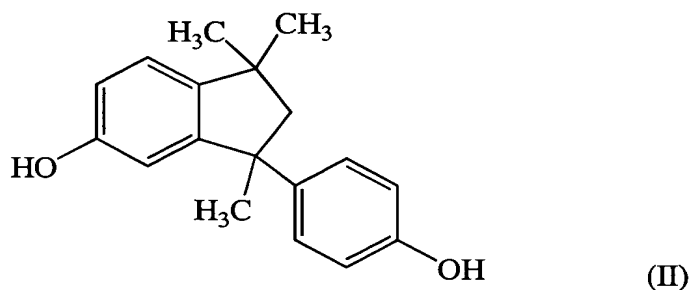
**[0015]** In the carbonate blocks of the copolyestercarbonates each R<sup>2</sup> of Formula (I) is independently an organic radical derived from a dihydroxy compound. For the most

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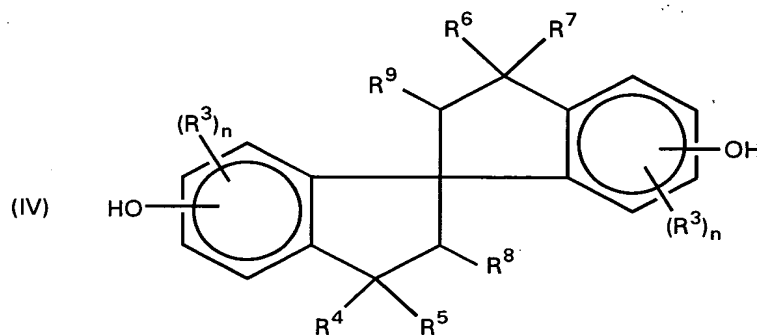
part, at least about 60 percent of the total number of  $R^2$  groups in the polymer are aromatic organic radicals and the balance thereof are aliphatic, alicyclic, or aromatic radicals. Suitable  $R^2$  radicals include, but are not limited to, m-phenylene, p-phenylene, 4,4'-biphenylene, 4,4'-bi(3,5-dimethyl)phenylene, 2,2-bis(4-phenylene)propane and similar radicals such as those which correspond to the dihydroxy-substituted aromatic hydrocarbons disclosed by name or formula (generic or specific) in U.S. Patent 4,217,438. In some embodiments of the invention dihydroxy compounds include 6-hydroxy-1-(4'-hydroxyphenyl)-1,3,3-trimethylindane, 4,4'-(3,3,5-trimethylcyclohexylidene)diphenol; 1,1-bis(4-hydroxy-3-methylphenyl)cyclohexane; 2,2-bis(4-hydroxyphenyl)propane (commonly known as bisphenol-A); 4,4-bis(4-hydroxyphenyl)heptane; 2,2-bis(4-hydroxy-3,5-dimethylphenyl)propane; 2,2-bis(4-hydroxy-3-methylphenyl)propane; 2,2-bis(4-hydroxy-3-ethylphenyl)propane; 2,2-bis(4-hydroxy-3-isopropylphenyl)propane; 2,4'-dihydroxydiphenylmethane; bis(2-hydroxyphenyl)methane; bis(4-hydroxyphenyl)methane; bis(4-hydroxy-5-nitrophenyl)methane; bis(4-hydroxy-2,6-dimethyl-3-methoxyphenyl)methane; 1,1-bis(4-hydroxyphenyl)ethane; 1,1-bis(4-hydroxy-2-chlorophenyl)ethane; 2,2-bis(3-phenyl-4-hydroxyphenyl)-propane; bis(4-hydroxyphenyl)cyclohexylmethane; 2,2-bis(4-hydroxyphenyl)-1-phenylpropane; 3,5,3',5'-tetrachloro-4,4'-dihydroxyphenyl)propane; 2,4'-dihydroxyphenyl sulfone; 2,6-dihydroxy naphthalene; hydroquinone, resorcinol;  $C_{1-3}$  alkyl-substituted resorcinols. In a particular embodiment the dihydroxy compound comprises bisphenol A.

**[0016]** Suitable dihydroxy compounds also include those containing indane structural units such as represented by the Formula (II), which compound is 3-(4-hydroxyphenyl)-1,1,3-trimethylindan-5-ol, and by the Formula (III), which compound is 1-(4-hydroxyphenyl)-1,3,3-trimethylindan-5-ol :

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[0017] Included among suitable dihydroxy-substituted aromatic hydrocarbons are the 2,2,2',2'-tetrahydro-1,1'-spirobi[1H-indene]diols having Formula (IV) :



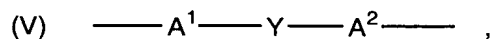
wherein each  $R^3$  is independently selected from monovalent hydrocarbon radicals and halogen radicals; each  $R^4$ ,  $R^5$ ,  $R^6$ , and  $R^7$  is independently  $C_{1-6}$  alkyl; each  $R^8$  and  $R^9$  is independently H or  $C_{1-6}$  alkyl; and each n is independently selected from positive integers having a value of from 0 to 3 inclusive. In a particular embodiment the 2,2,2',2'-tetrahydro-1,1'-spirobi[1H-indene]-diol is 2,2,2',2'-tetrahydro-3,3,3',3'-tetramethyl-1,1'-spirobi[1H-indene]-6,6'-diol (sometimes know as "SBI").

[0018] The term "alkyl" as used in the various embodiments of the present invention is intended to designate linear alkyl, branched alkyl, aralkyl, cycloalkyl, bicycloalkyl, tricycloalkyl and polycycloalkyl radicals containing carbon and hydrogen atoms, and

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optionally containing atoms in addition to carbon and hydrogen, for example atoms selected from Groups 15, 16 and 17 of the Periodic Table. Alkyl groups may be saturated or unsaturated, and may comprise, for example, vinyl and allyl. The term "alkyl" also encompasses that alkyl portion of alkoxide groups. In various embodiments normal and branched alkyl radicals are those containing from 1 to about 32 carbon atoms, and include as illustrative non-limiting examples C<sub>1</sub>-C<sub>32</sub> alkyl optionally substituted with one or more groups selected from C<sub>1</sub>-C<sub>32</sub> alkyl, C<sub>3</sub>-C<sub>15</sub> cycloalkyl or aryl; and C<sub>3</sub>-C<sub>15</sub> cycloalkyl optionally substituted with one or more groups selected from C<sub>1</sub>-C<sub>32</sub> alkyl. Some particular illustrative examples comprise methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, tertiary-butyl, pentyl, neopentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl and dodecyl. Some illustrative non-limiting examples of cycloalkyl and bicycloalkyl radicals include cyclobutyl, cyclopentyl, cyclohexyl, methylcyclohexyl, cycloheptyl, bicycloheptyl and adamantyl. In various embodiments aralkyl radicals are those containing from 7 to about 14 carbon atoms; these include, but are not limited to, benzyl, phenylbutyl, phenylpropyl, and phenylethyl. In various embodiments aryl radicals used in the various embodiments of the present invention are those substituted or unsubstituted aryl or heteroaryl radicals containing from 6 to 18 ring carbon atoms. Some illustrative non-limiting examples of these aryl radicals include C<sub>6</sub>-C<sub>15</sub> aryl optionally substituted with one or more groups selected from C<sub>1</sub>-C<sub>32</sub> alkyl, C<sub>3</sub>-C<sub>15</sub> cycloalkyl or aryl. Some particular illustrative examples of aryl radicals comprise substituted or unsubstituted phenyl, biphenyl, toluyl and naphthyl. Heteroaryl groups comprise those containing from about 3 to about 10 ring carbon atoms, and include, but are not limited to, triazinyl, pyrimidinyl, pyridinyl, furanyl, thiazolinyl and quinolinyl.

**[0019]** In some embodiments each R<sup>2</sup> is an aromatic organic radical and in particular embodiments a radical of the Formula (V):



wherein each A<sup>1</sup> and A<sup>2</sup> is a monocyclic divalent aryl radical and Y is a bridging radical in which one or two carbon atoms separate A<sup>1</sup> and A<sup>2</sup>. The free valence bonds in Formula (V) are usually in the meta or para positions of A<sup>1</sup> and A<sup>2</sup> in



relation to Y. Compounds in which  $R^2$  has Formula (V) are bisphenols, and for the sake of brevity the term "bisphenol" is sometimes used herein to designate the dihydroxy-substituted aromatic hydrocarbons; it should be understood, however, that non-bisphenol compounds of this type may also be employed as appropriate.

[0020] In Formula (V),  $A^1$  and  $A^2$  typically represent unsubstituted phenylene or substituted derivatives thereof, illustrative substituents (one or more) being alkyl, alkenyl, and halogen (particularly bromine). In many embodiments  $A^1$  and  $A^2$  represent unsubstituted phenylene radicals. Both  $A^1$  and  $A^2$  may be p-phenylene, although both may be o- or m-phenylene or one o- or m-phenylene and the other p-phenylene.

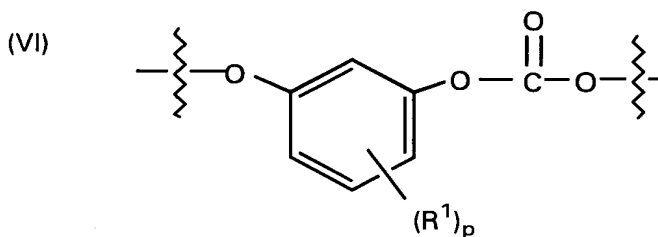
[0021] The bridging radical, Y, is one in which one or two atoms, separate  $A^1$  from  $A^2$ . In a particular embodiment one atom separates  $A^1$  from  $A^2$ . Illustrative radicals of this type are -C=O, -O-, -S-, -SO- or -SO<sub>2</sub>-, methylene, cyclohexylmethylene, 2-[2.2.1]-bicycloheptylmethylene, ethylene, isopropylidene, neopentylidene, cyclohexylidene, cyclopentadecylidene, cyclododecylidene, and adamantylidene. In some embodiments such radicals are gem-alkylene radicals. Also included, however, are unsaturated radicals. For reasons of availability and particular suitability for the purposes of this invention a particular bisphenol is 2,2-bis(4-hydroxyphenyl)propane (hereinafter referred to as bisphenol A or BPA), in which Y is isopropylidene and  $A^1$  and  $A^2$  are each p-phenylene.

[0022] Depending upon whether or not any unreacted 1,3-dihydroxybenzene moiety is present in the reaction mixture as described hereinafter,  $R^2$  in the carbonate blocks may consist of or at least partially comprise a radical derived from a 1,3-dihydroxybenzene moiety. Therefore, in one embodiment of the present invention the copolyestercarbonates comprise carbonate blocks with  $R^2$  radicals derived from a dihydroxy compound identical to at least one 1,3-dihydroxybenzene moiety in the polyarylate blocks. In another embodiment the copolyestercarbonates comprise carbonate blocks with  $R^2$  radicals derived from a dihydroxy compound different from any 1,3-dihydroxybenzene moiety in the polyarylate blocks. In yet another embodiment the copolyestercarbonates comprise carbonate blocks containing a

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mixture of  $R^2$  radicals derived from dihydroxy compounds at least one of which is the same as and at least one of which is different from any 1,3-dihydroxybenzene moiety in the polyarylate blocks. When a mixture of  $R^2$  radicals derived from dihydroxy compounds is present, then the molar ratio of dihydroxy compounds identical to those present in the polyarylate blocks to those dihydroxy compounds different from those present in the polyarylate blocks is typically about 1:999 to 999:1. In some particular embodiments the copolyestercarbonates comprise carbonate blocks containing a mixture of  $R^2$  radicals derived from at least two of unsubstituted resorcinol, a substituted resorcinol, and bisphenol A.

[0023] Diblock, triblock, and multiblock copolyestercarbonates are encompassed in the present invention. The chemical linkages between blocks comprising arylate chain members and blocks comprising organic carbonate chain members typically comprise a carbonate linkage between a diphenol residue of an arylate moiety and a  $-(C=O)-O-$  moiety of an organic carbonate moiety, although other types of linkages such as ester and/or anhydride are also possible. A typical carbonate linkage between said blocks is shown in Formula (VI), wherein  $R^1$  and p are as previously defined :

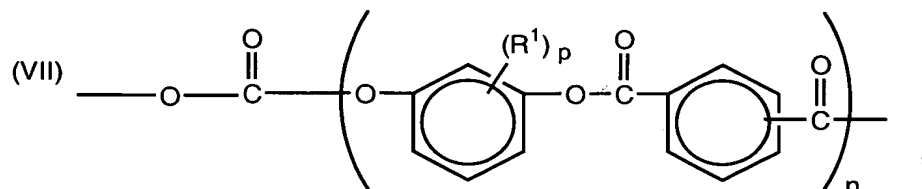


[0024] In one embodiment the copolyestercarbonate is substantially comprised of a diblock copolymer with a carbonate linkage between an arylate block and an organic carbonate block. In another embodiment the copolyestercarbonate is substantially comprised of a triblock carbonate-ester-carbonate copolymer with carbonate linkages between the arylate block and organic carbonate end-blocks. Copolyestercarbonates with at least one carbonate linkage between an arylate block and an organic carbonate block are typically prepared from 1,3-dihydroxybenzene arylate-containing oligomers

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containing at least one and often two hydroxy-terminal sites (hereinafter sometimes referred to as hydroxy-terminated polyester intermediate).

[0025] In another embodiment the copolyestercarbonate comprises arylate blocks linked by carbonate linkages as shown in Formula (VII) :



wherein  $R^1$ ,  $p$ , and  $n$  are as previously defined, and the arylate structural units are as described for Formula (I). Copolyestercarbonates comprising Formula (VII) may arise from reaction of hydroxy-terminated polyester intermediate with a carbonate precursor in the substantial absence of any dihydroxy compound different from the hydroxy-terminated polyester intermediate. In other embodiments the copolyestercarbonate may comprise a mixture of copolyestercarbonates with different structural units and different architectures, for example as described herein.

[0026] In the copolyestercarbonates suitable for use in the present invention the distribution of the blocks may be such as to provide a copolymer having any desired weight proportion of arylate blocks in relation to carbonate blocks. The copolyestercarbonates contain in one embodiment about 5% to about 99% by weight arylate blocks; in another embodiment about 20% to about 98% by weight arylate blocks; in another embodiment about 40% to about 98% by weight arylate blocks; in another embodiment about 60% to about 98% by weight arylate blocks; in another embodiment about 80% to about 96% by weight arylate blocks; and in still another embodiment about 85% to about 95% by weight arylate blocks.

[0027] The copolyestercarbonate film can comprise other components such art-recognized additives including, but not limited to, stabilizers, color stabilizers, heat stabilizers, light stabilizers, auxiliary UV screeners, auxiliary UV absorbers, flame retardants, anti-drip agents, flow aids, plasticizers, ester interchange inhibitors, antistatic agents, mold release agents, and colorants such as metal flakes, glass flakes

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and beads, ceramic particles, other polymer particles, dyes and pigments which may be organic, inorganic or organometallic. In a particular embodiment a copolyestercarbonate-comprising layer is substantially transparent.

[0028] The thickness of the coating layer is sufficient to provide protection of the underlying layers from weathering, in particular from the effects of UV radiation, as measured, for example, by retention of such properties as gloss and by color stability in any colorant-comprising layer. In one embodiment the thickness of the coating layer is in a range of about 2-2,500 microns, in another embodiment in a range of about 10-250 microns, and in another embodiment in a range of about 50-175 microns.

[0029] If desired, an overlayer may be included over the coating layer, for example to provide abrasion or scratch resistance. In a particular embodiment a silicone overlayer is provided over a copolyestercarbonate-comprising coating layer.

[0030] Multilayer articles of the present invention comprise a second layer comprising a polymer comprising carbonate structural units. In one embodiment the polymer of the second layer comprises at least one homopolycarbonate. Any polycarbonate capable of being processed into a film or sheet is suitable. In various embodiments suitable polycarbonates comprise those with structural units derived from monomers selected from the group consisting of all those described above for use in the carbonate blocks of the block copolyestercarbonate. In particular embodiments polycarbonate film comprises bisphenol A homo- or copolycarbonates. In another particular embodiment polycarbonate film comprises bisphenol A homopolycarbonate. In other embodiments polycarbonate film comprises a blend of at least one first polycarbonate with at least one other polymeric resin, examples of which include, but are not limited to, a second polycarbonate differing from said first polycarbonate either in structural units or in molecular weight or in both these parameters, or a polyester, or an addition polymer such as acrylonitrile-butadiene-styrene copolymer or acrylonitrile-styrene-acrylate copolymer.

[0031] The second layer can comprise other components such as art-recognized additives including, but not limited to, stabilizers, color stabilizers, heat stabilizers,

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light stabilizers, UV screeners, UV absorbers, flame retardants, anti-drip agents, flow aids, plasticizers, ester interchange inhibitors, antistatic agents, mold release agents, fillers, and colorants such as metal flakes, glass flakes and beads, ceramic particles, other polymer particles, dyes and pigments which may be organic, inorganic or organometallic. In a particular embodiment a second layer further comprises at least one colorant. In another particular embodiment a second layer comprises both a bisphenol A polycarbonate and at least one colorant selected from the group consisting of dyes, pigments, glass flakes, and metal flakes. In a particular embodiment metal flake comprises aluminum flake. In another particular embodiment metal flake comprises aluminum flake which has dimensions of about 20-70 microns. Further examples of colorants include, but are not limited to, Solvent Yellow 93, Solvent Yellow 163, Solvent Yellow 114/Disperse Yellow 54, Solvent Violet 36, Solvent Violet 13, Solvent Red 195, Solvent Red 179, Solvent Red 135, Solvent Orange 60, Solvent Green 3, Solvent Blue 97, Solvent Blue 104, Solvent Blue 104, Solvent Blue 101, Macrolex Yellow E2R, Disperse Yellow 201, Disperse Red 60, Diaresin Red K, Colorplast Red LB, Pigment Yellow 183, Pigment Yellow 138, Pigment Yellow 110, Pigment Violet 29, Pigment Red 209, Pigment Red 209, Pigment Red 202, Pigment Red 178, Pigment Red 149, Pigment Red 122, Pigment Orange 68, Pigment Green 7, Pigment Green 36, Pigment Blue 60, Pigment Blue 15:4, Pigment Blue 15:3, Pigment Yellow 53, Pigment Yellow 184, Pigment Yellow 119, Pigment White 6, Pigment Red 101, Pigment Green 50, Pigment Green 17, Pigment Brown 24, Pigment Blue 29, Pigment Blue 28, Pigment Black 7, Lead Molybdates, Lead Chromates, Cerium Sulfides, Cadmium Sulfoselenide, and Cadmium Sulfide. Illustrative extending and reinforcing fillers include, but are not limited to, silica, silicates, zeolites, titanium dioxide, stone powder, glass fibers or spheres, carbon fibers, carbon black, graphite, calcium carbonate, talc, mica, lithopone, zinc oxide, zirconium silicate, iron oxides, diatomaceous earth, calcium carbonate, magnesium oxide, chromic oxide, zirconium oxide, aluminum oxide, crushed quartz, calcined clay, talc, kaolin, asbestos, cellulose, wood flour, cork, cotton and synthetic textile fibers, especially reinforcing fillers such as glass fibers, carbon fibers, and metal fibers.

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**[0032]** The thickness of the second layer is in one embodiment in a range of about 2-2,500 microns, in another embodiment in a range of about 10-1,000 microns, and in another embodiment in a range of about 50-600 microns. An adhesive layer may optionally be present between the copolyestercarbonate-comprising coating layer and the second layer comprising carbonate structural units. In various embodiments said optional adhesive layers comprise those known in the art which provide adhesion to a surface or layer comprising a polymer comprising carbonate structural units. In some embodiments said optional adhesive layer is transparent and in other embodiments said optional adhesive layer has the same color as the second layer.

**[0033]** In various embodiments polyurethanes suitable for use in the adhesive layer of multilayer articles of the invention comprise those known in the art which provide adhesion to a surface or layer comprising a polymer comprising carbonate structural units. Polyurethane adhesives are described in many reference such as in Handbook of Adhesive Technology, edited by A. Pizzi and K.L. Mittal, Marcel Dekker, Inc., 1994, pages 405-429, and in Handbook of Adhesives, edited by I. Skeist, Van Nostrand Reinhold, third edition, 1990, pages 359-380. Polyurethane adhesives typically comprise long polyol chains that are tied together by shorter hard segments formed by diisocyanate and chain extenders, if present. The polyol chains are typically referred to as soft segments which impart low-temperature flexibility and room-temperature elastomeric properties. Generally, the higher the soft segment concentration, the lower will be the modulus, tensile strength, and hardness, while elongation will increase. In some embodiments polyols for polyurethane adhesives comprise at least one polyol from at least one of three categories: polyether polyols, polyester polyols, and polyalkylene polyols including, but not limited to, polyols based on polybutadiene. In particular embodiment polyurethane adhesives comprise polyether polyols. In another particular embodiment polyurethane adhesives comprise a mixture of at least one polyether polyol and at least one polyester polyol. In some particular embodiments polyols comprise polytetramethylene ether glycol or hexamethylene glycol.

**[0034]** In particular embodiments suitable polyurethane adhesives include either one-component or two-component adhesive formulations. In particular embodiments

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suitable polyurethane adhesives include two-component adhesives which typically comprise a low-equivalent-weight isocyanate or isocyanate prepolymer that is cured with at least one of a low-equivalent-weight polyol or polyamine. In some embodiments suitable two-component adhesives comprise a first component with structural units derived from MDI (methylene diphenyl diisocyanate) and a second component comprising mixtures of amines and hydroxy-containing compounds. In other embodiments suitable polyurethane adhesives comprise at least one component with structural units derived from methylene biscyclohexyl diisocyanate. The two-component adhesive may further comprise at least one filler such as crystalline silica or quartz, or carbon black.

[0035] In other embodiments polyurethane adhesives comprise a copolymer comprising polyurethane structural units. In a particular embodiment the polyurethane adhesive comprises a block copolymer comprising a thermoplastic polyurethane block. In another particular embodiment the polyurethane adhesive comprises a block copolymer comprising a thermoplastic polyurethane block and at least one block comprising structural units derived from styrene. In another particular embodiment the polyurethane adhesive comprises a block copolymer comprising a thermoplastic polyurethane block and a hydrogenated styrene block copolymer (HSBC) block. The HSBC block may be a hydrogenated styrene-diene block copolymer. Illustrative examples of such block copolymers include those available from Kuraray Corporation under the designation TU S5865.

[0036] In other embodiments suitable polyurethane adhesives are in the form of film or sheet, which in various embodiments may be optically clear or transparent. In a particular embodiment a suitable polyurethane adhesive film is an aliphatic thermoplastic polyurethane film. In various embodiments suitable polyurethane film has a softening point in one embodiment in a range of between about 70°C and about 200°C, and in another embodiment in a range of between about 80°C and about 160°C.

[0037] In still other embodiments suitable adhesive layers may comprise a blend of at least one polyurethane-comprising adhesive material and at least one additional

resinous material. The additional resinous material either improves or does not decrease the level of adhesion in the adhesive layer compared to the level of adhesion observed in a multilayer article comprising said adhesive layer in the absence of said additional resinous material. Suitable additional resinous materials are typically miscible or compatible with polyurethane-comprising adhesive materials. In some embodiments suitable additional resinous materials comprise those which are miscible with or compatible with that portion of a polyurethane-comprising copolymer which is not polyurethane.

[0038] In some particular embodiments a suitable additional resinous material comprises a resinous copolymer with structural units derived from at least one alkenyl aromatic compound and at least one conjugated diene which copolymer is miscible with or compatible with that portion of a polyurethane-comprising copolymer which comprises structural units derived from at least one alkenyl aromatic compound and at least one conjugated diene. In particular embodiments alkenyl aromatic compounds comprise styrene, alpha-methyl styrene, 2-methylstyrene, 3-methylstyrene, 4-methylstyrene, 2-t-butylstyrene, 3-t-butylstyrene, 4-t-butylstyrene, styrenes having from 1 to 5 halogen substituents on the aromatic ring, and the like, and combinations thereof. Conjugated dienes comprise butadiene, isoprene and the like. The resinous copolymer, and in particular the diene-derived structural units of the copolymer, may be hydrogenated or unhydrogenated. Suitable resinous copolymers may include those with linear, star, diblock, triblock or radial structure. The resinous copolymer comprising an alkenyl aromatic compound and a conjugated diene may be a random copolymer, a partial random copolymer or a block copolymer such as, but not limited to, an A-B, A-B-A or A-B-A-B block copolymer wherein "A" and "B" represent an alkenyl aromatic compound and a conjugated diene block respectively. In some particular embodiments suitable resinous copolymers comprise structural units derived from styrene and at least one conjugated diene, illustrative examples of which include, but are not limited to, polystyrene-b-poly(butadiene) copolymer (SB); polystyrene-b-poly(isoprene)-b-polystyrene copolymer (SIS); polystyrene-b-poly(butadiene)-b-polystyrene copolymer (SBS); polystyrene-b-poly(ethylene-propylene)-b-polystyrene copolymer (SEPS); polystyrene-b-poly(ethylene-butylene)-



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b-polystyrene copolymer (SEBS); and polystyrene-b-poly(ethylene-ethylene/propylene)-b-polystyrene copolymer (SEEPS). Suitable resinous copolymers typically comprise about 10-80 wt.% or 12-70 wt.% or 12-65 wt.% structural units derived from an alkenyl aromatic compound such as styrene. In a particular embodiment suitable resinous copolymers for use in blends with polyurethane-comprising adhesives comprise elastomeric polystyrene-b-poly(styrene-butadiene)-b-polystyrene copolymer (S-S/B-S) block copolymers containing a statistical S/B sequence and containing up to about 65 wt. % structural units derived from styrene. Illustrative examples of S-S/B-S block copolymers include STYROFLEX available from BASF Corporation. In a particular embodiment a suitable S-S/B-S block copolymer has a block length ratio of 15:70:15, wherein the S/B mid-block is a statistical or random copolymer of styrene and butadiene.

[0039] In another particular embodiment suitable resinous copolymers for use in blends with polyurethane-comprising adhesives comprise elastomeric polystyrene-b-poly(isoprene)-b-polystyrene (S-I-S) or hydrogenated S-I-S (hS-I-S) block copolymers wherein the isoprene linkages are primarily 1,2 or 3,4 linkages. Illustrative examples of such copolymers comprise HYBRAR, obtained from Kuraray Co. HYBRAR is a block copolymer comprising polystyrene end blocks and a vinyl-bonded, polyisoprene-rich middle block, optionally hydrogenated. In a preferred embodiment the block comprising polyisoprene units in HYBRAR is hydrogenated. Usually at least about 50% of the isoprene linkages of S-I-S and hS-I-S copolymers are 1,2 or 3,4 linkages with the remainder of the isoprene linkages being 1,4 linkages. In some particular embodiments about 55% or about 70% of the isoprene linkages of S-I-S or hS-I-S copolymers are 1,2 or 3,4 linkages. The preferred S-I-S or hS-I-S copolymer comprises greater than about 10% and less than about 30% units derived from styrene with the remainder comprised of structural units derived from isoprene. A particularly preferred S-I-S or hS-I-S copolymer has about 20% units derived from styrene with the remainder comprised of structural units derived from isoprene. In another particular embodiment a suitable tielayer comprises a blend of an S-S/B-S or S-B-S block copolymer with an S-I-S or hS-I-S copolymer.

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**[0040]** In other embodiments suitable resinous copolymers for use in blends with polyurethane-comprising adhesives comprise those with structural units derived from at least one alkenyl aromatic compound and at least one conjugated diene and which further comprise structural units derived from at least one polar functionalization agent selected from the group consisting of acrylic acid, methacrylic acid, maleic acid, maleic anhydride, itaconic acid, itaconic anhydride, fumaric acid, malic acid and monoesters of maleic acid and fumaric acid with monohydric alcohols. In some embodiments a suitable resinous copolymer is one that has been modified with maleic anhydride. In a particular embodiment a suitable resinous copolymer is an S-EB-S type block polymer which has been grafted with maleic anhydride. Suitable resinous copolymers suitable for use in blends with polyurethane-comprising adhesives typically have a glass transition temperature as measured by DSC of less than about 10°C, or less than about 0°C, or less than about minus 15°C, or less than about minus 20°C, or less than about minus 30°C.

**[0041]** In various embodiments polyurethane adhesive layer thickness may be in a range of between about 8 microns and about 2500 microns; in other embodiments in a range of between about 25 microns and about 2000 microns; in other embodiments in a range of between about 50 microns and about 1500 microns; in other embodiments in a range of between about 100 microns and about 1300 microns; and in still other embodiments in a range of between about 500 microns and about 1300 microns. In some other embodiments polyurethane adhesive layer thickness may be in a range of between about 10 microns and about 650 microns; in other embodiments in a range of between about 25 microns and about 400 microns; and in still other embodiments in a range of between about 50 microns and about 260 microns.

**[0042]** In some embodiments of the present invention a polyurethane adhesive contains little or no free amine in the cured adhesive. Although the invention is not dependent upon any particular theory of operation, it is possible that amine groups may cause polycarbonate molecular weight degradation leading to deterioration in certain properties of the polycarbonate-comprising multilayer article. In some cases molecular weight degradation in the polycarbonate may result in decrease in adhesive strength under certain conditions such as after exposure to temperature-humidity cycle

testing. In other embodiments a polyurethane adhesive further comprises additives known in the art including, but not limited to, adhesion promoters and tackifiers.

[0043] It is well known that mismatch between coefficients of thermal expansion (CTE) of a cap layer or coating layer and an underlying substrate may induce very high thermal stress and cause delamination in the final multilayer articles. In various embodiments the polyurethane adhesive layer can be formulated for applications with multilayer articles comprising said second layer and substrate layer with different coefficients of thermal expansion (CTE), for example, a high CTE second layer on a low CTE substrate. In various embodiments the polyurethane-comprising adhesive layer has a modulus at room temperature in one embodiment in a range of between about  $10^5$  and about  $10^9$  Pascals and in another embodiment in a range of between about  $10^6$  and  $10^8$  Pascals.

[0044] The material of the substrate layer in the articles of this invention may comprise at least one material selected from the group consisting of a thermoplastic resin, a cured thermoset resin, a metal, a ceramic, a glass, and a cellulosic material. There is no particular limitation on the thickness of the substrate layer provided that a multilayer article comprising the substrate can be processed into a final desired form. In a particular embodiment the material of the substrate layer may be at least one thermoplastic polymer, whether addition or condensation prepared. Thermoplastic polymers include, but are not limited to, polycarbonates, particularly aromatic polycarbonates, polyacetals, polyarylene ethers, polyphenylene ethers, polyarylene sulfides, polyphenylene sulfides, polyimides, polyamideimides, polyetherimides, polyetherketones, polyaryletherketones, polyetheretherketones, polyetherketoneketones, polyamides, copolyamides, polyesters, liquid crystalline polyesters, polyetheresters, polyetheramides, polyesteramides, and polyestercarbonates (other than those employed for the coating layer, as defined herein). In some embodiments polycarbonates and polyesters are preferred. A substrate layer may additionally contain art-recognized additives including, but not limited to, colorants, pigments, dyes, impact modifiers, stabilizers, color stabilizers, heat stabilizers, light stabilizers, UV screeners, UV absorbers, flame retardants, anti-

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drip agents, fillers, flow aids, plasticizers, ester interchange inhibitors, antistatic agents, and mold release agents.

[0045] Suitable substrate polycarbonates (sometimes referred to hereinafter as "PC") comprise those with structural units derived from monomers selected from the group consisting of all those described above for use in the carbonate blocks of the block copolyestercarbonate. In some embodiments the polycarbonates are bisphenol A homo- and copolycarbonates. In other embodiments a suitable polycarbonate is one which is different from that polycarbonate layer which is in contact with the copolyestercarbonate coating layer. In various embodiments the weight average molecular weight of a substrate polycarbonate ranges from about 5,000 to about 100,000; in other embodiments the weight average molecular weight of a substrate polycarbonate ranges from about 25,000 to about 65,000.

[0046] The polycarbonate substrate may also be a copolyestercarbonate (other than that copolyestercarbonate employed for the coating layer as defined herein). Such copolymers typically comprise, in addition to the organic carbonate units, ester units such as isophthalate and/or terephthalate. In various embodiments copolyestercarbonates which find use as substrates in the instant invention and the methods for their preparation are disclosed in, for example, U.S. Patent Nos. 3,030,331; 3,169,121; 3,207,814; 4,194,038; 4,156,069; 4,238,596; 4,238,597; 4,487,896; and 4,506,065.

[0047] Polyester substrates include, but are not limited to, poly(alkylene dicarboxylates), especially poly(ethylene terephthalate) (sometimes referred to hereinafter as "PET"), poly(1,4-butylene terephthalate) (sometimes referred to hereinafter as "PBT"), poly(trimethylene terephthalate), poly(ethylene naphthalate), poly(butylene naphthalate), poly(cyclohexanedimethanol terephthalate), poly(cyclohexanedimethanol-co-ethylene terephthalate), and poly(1,4-cyclohexanedimethyl-1,4-cyclohexanedicarboxylate). Also included are polyarylates, illustrative examples of which include those comprising structural units derived from bisphenol A, terephthalic acid, and isophthalic acid.

**[0048]** Suitable addition polymer substrates include homo- and copolymeric aliphatic olefin and functionalized olefin polymers (which are homopolymers and copolymers comprising structural units derived from aliphatic olefins or functionalized olefins or both), and their alloys or blends. Illustrative examples include, but are not limited to, polyethylene, polypropylene, thermoplastic polyolefin (TPO), ethylene-propylene copolymer, poly(vinyl chloride), poly(vinyl chloride-co-vinylidene chloride), poly(vinyl fluoride), poly(vinylidene fluoride), poly(vinyl acetate), poly(vinyl alcohol), poly(vinyl butyral), poly(acrylonitrile), acrylic polymers such as those of (meth)acrylamides or of alkyl (meth)acrylates such as poly(methyl methacrylate) (PMMA), and polymers of alkenylaromatic compounds such as polystyrenes, including syndiotactic polystyrene. In some embodiments addition polymer substrates are polystyrenes and especially the so-called acrylonitrile-butadiene-styrene (ABS) and acrylonitrile-styrene-acrylate (ASA) copolymers, which may contain thermoplastic, non-elastomeric styrene-acrylonitrile side chains grafted on an elastomeric base polymer of butadiene and alkyl acrylate, respectively.

**[0049]** Blends of any of the foregoing polymers may also be employed as substrates. Typical blends include, but are not limited to, those comprising PC/ABS, PC/ASA, PC/PBT, PC/PET, PC/polyetherimide, PC/polysulfone, polyester/polyetherimide, PMMA/acrylic rubber, polyphenylene ether-polystyrene, polyphenylene ether-polyamide or polyphenylene ether-polyester. Although the substrate layer may incorporate other thermoplastic polymers, the above-described polycarbonates and/or addition polymers often constitute the major proportion thereof.

**[0050]** The substrate layer in the multilayer articles of this invention may also comprise at least one of any cured thermoset polymer (referred to sometimes for convenience as "thermoset polymer"). Suitable thermoset polymer substrates include, but are not limited to, those derived from epoxys, cyanate esters, unsaturated polyesters, diallylphthalate, acrylics, alkyds, phenol-formaldehyde, novolacs, resoles, bismaleimides, PMR resins, melamine-formaldehyde, urea-formaldehyde, benzocyclobutanes, hydroxymethylfurans, and isocyanates. In one embodiment of the invention the thermoset polymer substrate comprises a RIM material. In another embodiment of the invention the thermoset polymer substrate further comprises at

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least one thermoplastic polymer, such as, but not limited to, polyphenylene ether, polyphenylene sulfide, polysulfone, polyetherimide, polyamide or polyester. Said thermoplastic polymer is typically combined with thermoset monomer mixture before curing of said thermoset. In a particular embodiment a substrate of the invention comprises an acrylic ester-derived thermoset resin containing a polyphenylene ether.

**[0051]** In one embodiment of the invention a thermoplastic or cured thermoset substrate layer also incorporates at least one filler and/or colorant. Illustrative extending and reinforcing fillers, and colorants include silica, silicates, zeolites, titanium dioxide, stone powder, glass fibers or spheres, carbon fibers, carbon black, graphite, calcium carbonate, talc, mica, lithopone, zinc oxide, zirconium silicate, iron oxides, diatomaceous earth, calcium carbonate, magnesium oxide, chromic oxide, zirconium oxide, aluminum oxide, crushed quartz, calcined clay, talc, kaolin, asbestos, cellulose, wood flour, cork, cotton and synthetic textile fibers, especially reinforcing fillers such as glass fibers, carbon fibers, and metal fibers, as well as colorants such as metal flakes, glass flakes and beads, ceramic particles, other polymer particles, dyes and pigments which may be organic, inorganic or organometallic. In the present context a thermoplastic resin in powder or fiber form included in a cured thermoset substrate may also be considered a filler. In some particular embodiments a cured thermoset substrate of the invention comprises a filled thermoset substrate layer selected from the group consisting of sheet-molding compound (SMC), vinyl ester SMC, bulk molding compound (BMC), thick molding compound (TMC), structural reaction injected molded compound (SRIM), and an acrylic ester-derived thermoset resin comprising a polyphenylene ether. Sheet molding compound (SMC) is a moldable composite material often comprising an unsaturated liquid polyester resin, a low profile thermoplastic resin, an inert filler, a curing aid, and short lengths of glass fiber reinforcing materials. Among illustrative fiberglass reinforced thermoset substrates suitable for use in the invention are those provided by Ashland Specialty Chemical, Dublin, Ohio, GenCorp, Marion, Ind., Rockwell International Corporation, Centralia, Ill., Budd Company, Madison Heights, Mich., and Eagle Picher Plastics, Grabill, Ind.. The SRIM substrates suitable for the use include, but are not limited to, those provided by Bayer, Pittsburgh, Pa.. Typical

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vinyl ester SMC substrates are manufactured by Dow, Midland, Mich. In a particular embodiment a suitable fiberglass reinforced thermoset substrate is a long fiber injection polyurethane (LFI-PU) foam.

[0052] The substrate layer may also comprise at least one cellulosic material including, but not limited to, wood, paper, cardboard, fiber board, particle board, plywood, construction paper, Kraft paper, cellulose nitrate, cellulose acetate butyrate, and like cellulosic-containing materials. The invention also encompasses blends of at least one cellulosic material and either at least one thermoset polymer (particularly an adhesive thermoset polymer), or at least one thermoplastic polymer (particularly a recycled thermoplastic polymer, such as PET or polycarbonate), or a mixture of at least one thermoset polymer and at least one thermoplastic polymer.

[0053] Multilayer articles encompassed by the invention also include those comprising at least one glass layer. Typically any glass layer is a substrate layer, although multilayer articles comprising a copolyestercarbonate coating layer interposed between a glass layer and a substrate layer are also contemplated. Depending upon the nature of coating and glass layers, at least one adhesive interlayer may be beneficially employed between any glass layer and any copolyestercarbonate coating layer. The adhesive interlayer may be transparent, opaque or translucent. For some embodiments it is preferred that any such interlayer be optically transparent in nature and generally have a transmission of greater than about 60% and a haze value less than about 3% with no objectionable color.

[0054] Metal articles exposed to UV-light may exhibit tarnishing and other detrimental phenomena. In another embodiment the invention encompasses multilayer articles comprising at least one metal layer as substrate layer. Representative metal substrates include those comprising brass, aluminum, magnesium, chrome, iron, steel, copper, and other metals or alloys or articles containing them, which may require protection from UV-light or other weather phenomena.

[0055] For metals to be used for applications such as automotive body panels, pretreatment of the metal surface may be necessary to clean the metal surfaces, for

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example to improve adhesion by providing an inert surface comprising a chemical conversion coating, and/or to prevent the spread of corrosion. Methods for surface treatment of metal substrates are known in the art and are described in many references, for example in *Automotive Paints and Coatings*, edited by G. Fettis, VCH Publishers, 1995. In some embodiments pretreatment is carried out in a number of stages, including 1) cleaning (rust removal, degreasing, rinsing), 2) chemical conversion coating, and 3) electrodeposition (normally referred as e-coating).

**[0056]** In another embodiment the present invention provides methods for making multilayer articles comprising the layer components described herein. In some embodiments the coating layer comprising a block copolyestercarbonate and the second layer comprising a polymer comprising carbonate structural units are formed into a copolyestercarbonate / carbonate-comprising polymer assembly comprising at least two layers. Such an assembly can be made by known methods such as by coextrusion of films or sheets of the two materials. In other embodiments such an assembly can be made by lamination, or solvent or melt coating. In a particular embodiment application of the coating layer to the second layer is performed in a melt process. Suitable methods for application include fabrication of a separate sheet of coating layer followed by application to the second layer, as well as simultaneous production of both layers. Thus, there may be employed such illustrative methods as molding, compression molding, thermoforming, co-injection molding, coextrusion, overmolding, multi-shot injection molding, sheet molding and placement of a film of the coating layer material on the surface of the second layer followed by adhesion of the two layers, typically in an injection molding apparatus; e.g., in-mold decoration. These operations may be conducted under art-recognized conditions.

**[0057]** Assemblies comprising coating layer and second layer may comprise the combined thicknesses of the layers. Such an assembly has a thickness in some embodiments in a range between about 10 microns and about 2500 microns; in other embodiments in a range between about 10 microns and about 1000 microns; in other embodiments in a range between about 10 microns and about 500 microns; and in still other embodiments in a range between about 10 microns and about 250 microns



**[0058]** In some embodiments the polyurethane adhesive layer in a paste or low viscosity liquid form may be applied by methods known in the art, including, but not limited to, roller, brush, or spray with a wet film thickness of about 0.2 microns to about 1200 microns to a substrate. The copolyestercarbonate / carbonate-comprising polymer assembly can then be formed adjacent to the adhesion layer upon the substrate layer by use of known methods, for example lamination using heat and pressure as in compression molding or using other forming techniques such as vacuum forming or hydroforming. Alternatively, polyurethane adhesive layer in a paste or low viscosity liquid form may be applied by methods known in the art to at least one side of said second layer either before or after formation of an assembly of second layer with coating layer, followed by formation and bonding of the combined layers adjacent to the substrate layer. Alternatively, the said second layer can be formed adjacent to the substrate layer comprising a polyurethane adhesive, followed by formation of coating layer adjacent to the second layer. After application to either substrate layer or second layer, the polyurethane-comprising adhesive may optionally be partially cured before formation of the multilayer article by combination of the adhesive-comprising assembly with remaining layers.

**[0059]** For polyurethane-comprising adhesive already in film form the multilayer article may be formed by combining the various layers comprising coating layer, second layer, adhesive layer and substrate by methods known in the art. In one embodiment a copolyestercarbonate / carbonate-comprising polymer assembly and separate adhesive layer may be combined by known methods with substrate layer to form the multilayer article. Known methods include, but are not limited to, lamination and compression molding. Alternatively, the adhesive layer can be formed adjacent to the copolyestercarbonate / carbonate-comprising polymer assembly either after or during a process (such as coextrusion) to make said assembly, and become an integral part of the film assembly which can subsequently be directly formed adjacent to the substrate layer using known processes, for example by use of such methods as heat and pressure. Alternatively, said second layer can be formed adjacent to thermoplastic polyurethane adhesive film for example by directly coextruding said layers together, followed by formation of an assembly with copolyestercarbonate

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coating layer using known methods which include, but are not limited to, lamination and compression molding. Said assembly can subsequently be directly formed adjacent to the substrate layer using known processes. The copolyestercarbonate / carbonate-comprising polymer assembly can be optionally thermoformed to the approximate shape of the article before molding. In various embodiments any formation step of one layer adjacent to another layer may be performed by known methods which include, but are not limited to, extrusion coating, lamination and compression molding.

**[0060]** It is also within the scope of the invention to apply a structure comprising the coating layer, second layer, and polyurethane adhesive layer to a substrate layer. This may be achieved by known methods, for example in one embodiment, by charging an injection mold with the structure comprising the coating layer, second layer, and polyurethane adhesive layer, and injecting the substrate or substrate precursors behind it. By this method, in-mold decoration and the like are possible. In one embodiment both sides of the substrate layer may receive the other layers, while in another embodiment they are applied to only one side of the substrate layer.

**[0061]** The multilayer articles comprising the various layer components of this invention are typically characterized by the usual beneficial properties of the substrate layer, in addition to weatherability as may be evidenced by such properties as improved initial gloss, improved initial color, improved resistance to ultraviolet radiation and maintenance of gloss, improved impact strength, and resistance to organic solvents encountered in their final applications. Depending upon such factors as the coating layer/substrate combination, the multilayer articles may possess recycling capability, which makes it possible to employ the regrind material as a substrate for further production of articles of the invention. The multilayer articles often exhibit low internal thermal stress induced from CTE mismatch between layers. The multilayer articles may also possess excellent environmental stability, for example thermal and hydrolytic stability. In embodiments of the invention the multilayer article exhibits a ninety-degree peel strength that is greater than that observed in a similar multilayer article made without tielayer. In other embodiments the multilayer article exhibits a ninety-degree peel strength of at least 700 Newtons

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per meter. In still other embodiments the multilayer article exhibits a ninety-degree peel strength of at least 1750 Newtons per meter.

**[0062]** In some specific embodiments the multilayer article may be prepared by a method which is selected from the group consisting of the method (i) comprising the steps of (a) preparing an assembly of coating layer and second layer, and (b) combining said assembly with separate adhesive layer and substrate layer; the method (ii) comprising the steps of (a) preparing an assembly of coating layer and second layer, (b) forming the adhesive layer adjacent to the substrate layer, and (c) combining said assembly with the adhesive layer / substrate layer combination; and the method (iii) comprising the steps of (a) preparing an assembly of coating layer, second layer, and adhesive layer, and (b) forming said assembly adjacent to the substrate layer.

**[0063]** Multilayer articles which can be made which comprise the various layer components of this invention include articles for OVAD applications; exterior and interior components for aircraft, automotive, truck, military vehicle (including automotive, aircraft, and water-borne vehicles), scooter, and motorcycle, including panels, quarter panels, rocker panels, vertical panels, horizontal panels, trim, pillars, center posts, fenders, doors, decklids, trunklids, hoods, bonnets, roofs, bumpers, fascia, grilles, mirror housings, pillar appliques, cladding, body side moldings, wheel covers, hubcaps, door handles, spoilers, window frames, headlamp bezels, headlamps, tail lamps, tail lamp housings, tail lamp bezels, license plate enclosures, roof racks, and running boards; enclosures, housings, panels, and parts for outdoor vehicles and devices; wind turbine blades and housings; enclosures for electrical and telecommunication devices; outdoor furniture; aircraft components; boats and marine equipment, including trim, enclosures, and housings; outboard motor housings; depth finder housings, personal water-craft; jet-skis; pools; spas; hot-tubs; steps; step coverings; building and construction applications such as glazing, roofs, windows, floors, decorative window furnishings or treatments; treated glass covers for pictures, paintings, posters, and like display items; optical lenses; ophthalmic lenses; corrective ophthalmic lenses; implantable ophthalmic lenses; wall panels, and doors; counter tops; protected graphics; outdoor and indoor signs; enclosures, housings, panels, and parts for automatic teller machines (ATM); enclosures, housings, panels, and parts for

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lawn and garden tractors, lawn mowers, and tools, including lawn and garden tools; window and door trim; sports equipment and toys; enclosures, housings, panels, and parts for snowmobiles; recreational vehicle panels and components; playground equipment; shoe laces; articles made from plastic-wood combinations; golf course markers; utility pit covers; computer housings; desk-top computer housings; portable computer housings; lap-top computer housings; palm-held computer housings; monitor housings; printer housings; keyboards; FAX machine housings; copier housings; telephone housings; phone bezels; mobile phone housings; radio sender housings; radio receiver housings; light fixtures; lighting appliances; reflectors; network interface device housings; transformer housings; air conditioner housings; cladding or seating for public transportation; cladding or seating for trains, subways, or buses; meter housings; antenna housings; cladding for satellite dishes; coated helmets and personal protective equipment; coated synthetic or natural textiles; coated photographic film and photographic prints; coated painted articles; coated dyed articles; coated fluorescent articles; coated foam articles; and like applications. The invention further contemplates additional fabrication operations on said articles, such as, but not limited to, molding, in-mold decoration, baking in a paint oven, lamination, and/or thermoforming.

**[0064]** Without further elaboration, it is believed that one skilled in the art can, using the description herein, utilize the present invention to its fullest extent. The following examples are included to provide additional guidance to those skilled in the art in practicing the claimed invention. The examples provided are merely representative of the work that contributes to the teaching of the present application. Accordingly, these examples are not intended to limit the invention, as defined in the appended claims, in any manner.

**[0065]** In the following examples the copolyestercarbonate-polycarbonate film assembly comprised a layer of copolyestercarbonate film and a layer of polycarbonate film. The copolyestercarbonate film comprised a copolyestercarbonate with arylate structural units derived from unsubstituted resorcinol, isophthalic acid, and terephthalic acid, and carbonate structural units derived from bisphenol A. The polycarbonate film comprised bisphenol A polycarbonate. The abbreviation "PU"

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means polyurethane. The abbreviation "SMC" means sheet molding compound. SEPTON was obtained from Kuraray Corporation and was either polystyrene-b-poly(ethylene-propylene)-b-polystyrene copolymer (SEPS) or polystyrene-b-poly(ethylene-butylene)-b-polystyrene copolymer (SEBS) or polystyrene-b-poly(ethylene-ethylene/propylene)-b-polystyrene copolymer (SEBS) containing about 13-65 wt.% structural units derived from styrene. In a particular embodiment SEPTON 8006 was a polystyrene-b-poly(ethylene-butylene)-b-polystyrene copolymer (SEBS) containing about 33 wt.% structural units derived from styrene. KURAMIRON was obtained from Kuraray Corporation and was a thermoplastic polyurethane elastomer. In a particular embodiment KURAMIRON 8165 was a polyester type polyurethane. CYCOLAC was an acrylonitrile-butadiene-styrene (ABS) resin obtained from General Electric Plastics. CYCOLOY was a blend of bisphenol A polycarbonate and acrylonitrile-butadiene-styrene resin obtained from General Electric Plastics. GELOY was an acrylonitrile-styrene-acrylate (ASA) resin obtained from General Electric Plastics. GTX was a compatibilized blend of polyphenylene ether and polyamide obtained from General Electric Plastics. VALOX was a poly(butylene terephthalate) obtained from General Electric Plastics.

[0066] The abbreviation "TSN" means thermoset NORYL, a material obtained from General Electric Plastics. TSN comprised a major amount of a polyphenylene ether and a minor amount of a vinyl monomer composition, along with various amounts of fillers, additives, and curing agents. The polyphenylene ether was preferably a poly(2,6-dimethyl-1,4-phenylene ether) (PPE) or poly(2,6-dimethyl-1,4-phenylene-co-2,3,6-trimethyl-1,4-phenylene ether), wherein greater than 5%, more preferably greater than 50%, most preferably greater than 90% of the polyphenylene ether hydroxyl groups have been capped. The capping group may contain acrylic, methacrylic or allylic functionality, and preferably methacrylic functionality. The polyphenylene ether may contain internal olefinic groups produced, for example, by reaction of internal repeat units with an alkenyl halide or alkenoyl halide or unsaturated carboxylic acid anhydride, such as allyl bromides, methacrylic acid halides, or methacrylic acid anhydrides. Such reaction may take place in the presence or absence of a basic reagent such as an amine or alkyl lithium reagent. The vinyl monomer

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composition comprised one or more monomers selected from the group consisting of a styrenic, acrylic and allylic monomer, preferably a blend of two or more of these monomers; more preferably a blend of a styrenic and an acrylic monomer; and most preferably a blend of styrene and a polyfunctional acrylate. TSN may contain from 0.5-95%, preferably 5-60% and most preferably 10-50% by weight polyphenylene ether. TSN may also contain from 95-0.5% by weight of a vinyl monomer composition. Such compositions may further contain other initiators; colorants; fillers, both polymeric, organic and inorganic; additives such as mold release agents; low profile additives; and the like. Inorganic fillers such as calcium carbonate are often included at levels of 0-250 parts by weight based on the TSN composition. Various combinations possible in the thermoset NORYL composition are further described in U.S. Patent Application 20020028337.

[0067] Samples were cut into 2.54 centimeter (cm) wide stripes and tested for peel resistance of the polyurethane adhesive bond using a 90-degree peel test with a crosshead separation speed of 2.54 cm per minute using an Instron testing device (Model 4505). This adhesion test method is well known to those skilled in the art and is generally described in such references as U.S. Patent No. 3,965,057. The testing apparatus in this test procedure consisted of a series of movable rollers or supports which allowed the test specimen to be peeled at a constant 90-degree angle along its entire uncut length. The apparatus consisted of a series of five 1.3 cm rollers which were geometrically affixed to two side supports and a base plate. The two lower rollers were adjustable so that the apparatus could accommodate test specimens varying in thickness. A suitable top clamp was used for securing the plastic layer. The test specimen was 15.2 cm in length and 2.54 cm in width. It was insured that a portion of the test specimen remained unbonded. At least 3 specimens were tested for each adhesive sample. In the actual testing procedure, the fixture was affixed to the movable head of the testing machine in a position which would cause the peeled plastic layer to form a 90-degree angle with the test specimen during the test. The test specimen was positioned in the fixture and the free skin clamped securely. The clamp was then pinned to the top head of the testing machine. With no load on the test specimen, the weighing apparatus was then balanced to zero. Provision was made to

autograph the peel load versus displacement of the head for a peel distance of at least 10.2 cm. Neglecting the first 2.54 cm of peel, the load required to peel the plastic layer was taken from the autographic curve. The peel strength (P) was then calculated as follows:

$$P = \frac{\text{peeling load (Newtons)}}{\text{width of specimen (meters)}}$$

### EXAMPLES 1-3

[0068] Laminates of copolyestercarbonate-polycarbonate film assembly onto e-coated steel were prepared with PU adhesive tie-layer. The two-component PU tie-layer adhesives, ARALDITE 2040, 2042, and AW8680/HW8685, were obtained from Vantico Inc. (formerly Ciba Performance Specialty Polymers). ARALDITE 2040 comprised polymeric methylene diphenyl diisocyanate and a mixture of 2-hydroxypropylaniline, 1,2-diaminocyclohexane, 3-(triethoxysilyl)-1-propanamine, 2-ethyl-1,3-hexanediol, and quartz. ARALDITE 2042 comprised polymeric methylene diphenyl diisocyanate, 1,2-diaminocyclohexane, 2-ethyl-1,3-hexanediol, hydrogenated terphenyl, 2-hydroxypropylaniline, polybutadiene polyol, and quartz. AW8680/HW8685 comprised polymeric methylene diphenyl diisocyanate and a mixture of 2-hydroxypropylaniline, 1,2-diamino-cyclohexane, 2-ethyl-1,3-hexanediol, and carbon black. E-coated steel test panels were obtained from ACT Laboratories (ACT # APR 31330). The e-coated metal was electro-zinc galvanized steel typically used for automotive body panels which was cleaned, phosphate treated, and finally e-coated with PPG e-coating formulation (type ED5100). A copolyestercarbonate-polycarbonate film assembly was prepared by coextruding a 0.254 millimeter (mm) thick clear copolyestercarbonate film with a 0.5 mm thick pigmented, cranberry-colored polycarbonate layer containing metal flakes for metallic effects. The PU adhesive components were thoroughly mixed in paste form and uniformly applied to the dried e-coated metal substrates in a thin layer by using an application gun and attached static mixer pipe. A copolyestercarbonate-polycarbonate film assembly, which had been surface-washed with deionized water and oven dried, was then put on top of the adhesive with the polycarbonate film side in contact with the adhesive.

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This combined assembly was placed in a Carver press and heated on both sides under 689 kilopascals pressure for 10 to 90 minutes at temperatures given in the Table. The copolyestercarbonate-polycarbonate film assembly adhered well to the substrates. Samples were cut into 2.54 cm wide stripes and tested for adhesion using a 90-degree peel test as described above. The adhesion strength of the tie layer with copolyestercarbonate-polycarbonate film assembly and metal substrate was measured by the peel force in Newtons per meter (N/m). The adhesion results are shown in Table 1. In each example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the metal substrate was found to be excellent.

TABLE 1

Example	Adhesive	Molding temp. (°C)	Molding time (min.)	Peel force (N/m)	Failure mode
1	ARALDITE 2040	100	30	5779	Cohesive PU
2	ARALDITE 2042	100	10	4903	Interfacial PU/steel
3	AW8680 / HW8685	60	90	4028	Interfacial PC/PU

#### EXAMPLES 4-5

[0069] Laminates of copolyestercarbonate-polycarbonate film assembly onto cleaned and chemical conversion coated steel were prepared with PU tie-layer. A laminate was prepared according to Examples 1-3 with copolyestercarbonate-polycarbonate film assembly onto a cold-roll steel test panel (cleaning and chemical conversion pretreated) obtained from ACT Laboratories (ACT # APR 32488) using PU adhesives. The adhesion results are shown in Table 2. In each example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the metal substrate was found to be excellent.



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TABLE 2

Example	Adhesive	Molding temp. (°C)	Molding time (min.)	Peel force (N/m)	Failure mode
4	ARALDITE 2042	100	30	2802	Interfacial PU/steel
5	ARALDITE 2040	100	10	2101	Interfacial PU/steel

#### EXAMPLES 6-7

[0070] Laminates of copolyestercarbonate-polycarbonate film assembly onto SMC were prepared with PU tie-layer. Smooth surface, class “A” SMC was received from the Budd Company (Budd product #DSM-971) and comprised unsaturated polyester resin with curing agents and fillers. SMC prepreg was cured into a large panel at 149°C and 8273 kilopascals for 90 seconds. Test panels of dimension 10.2 cm by 15.2 cm were cut from the molded SMC panels and were cleaned with deionized water and dried. A laminate was prepared according to Examples 1-3 with copolyestercarbonate-polycarbonate film assembly onto the SMC test panel using PU adhesives. The adhesion results are shown in Table 3. In each example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the cured thermoset substrate was found to be excellent.

TABLE 3

Example	Adhesive	Molding temp. (°C)	Molding time (min.)	Peel force (N/m)	Failure mode
6	ARALDITE 2042	100	30	5954	Interfacial PU/SMC
7	ARALDITE 2040	100	10	7005	Cohesive PU

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#### EXAMPLES 8-9

[0071] Laminates of copolyestercarbonate-polycarbonate film assembly onto TSN were prepared with PU tie-layer. A TSN formulation was cured into a 30.5 cm by 30.5 cm panel at 150°C for 4 minutes under 6894 kilopascals pressure. Test panels of 10.2 cm by 15.2 cm dimensions were cut from the molded TSN panels and were cleaned with deionized water and dried. A laminate was prepared according to Examples 1-3 with copolyestercarbonate-polycarbonate film assembly onto the TSN test panel using PU adhesives. The adhesion results are shown in Table 4. In each example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the cured thermoset substrate was found to be excellent.

TABLE 4

Example	Adhesive	Molding temp. (°C)	Molding time (min.)	Peel force (N/m)	Failure mode
8	ARALDITE 2042	100	30	2802	Interfacial PU/TSN
9	ARALDITE 2040	100	10	2627	Interfacial PU/TSN

#### EXAMPLES 10-13

[0072] Laminates of copolyestercarbonate-polycarbonate film assembly with e-coated steel and chemical conversion coated steel were prepared. Aliphatic thermoplastic polyurethane film, grades PE393 and PE399, of 1.3 mm thickness were obtained from JPS Elastomerics Corp. DUREFLEX A4700 polyurethane film of 1.3 mm thickness was obtained from Deerfield Urethane, Inc. Each type of PU film was laminated to a copolyestercarbonate-polycarbonate film assembly at 110°C and 344 kilopascals for 2 minutes using a hot press. E-coated steel test panels were obtained from ACT Laboratories (ACT # APR26782). The e-coated metal was cold-roll steel which was cleaned, phosphate treated, and finally e-coated with PPG e-coating formulation. The copolyestercarbonate-polycarbonate film assembly with PU laminated to the polycarbonate side was then put on top of the e-coated steel substrate with PU film

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layer in contact with the metal surface. Each assembly was placed in a Carver press and heated on both sides under 689 kilopascals pressure and 127°C for 10 minutes. The copolyestercarbonate-polycarbonate film assembly adhered well to the substrates. The adhesion strength of the tie layer with copolyestercarbonate-polycarbonate film assembly and metal substrate was measured by the peel force. In each example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the metal substrate was found to be excellent.

TABLE 5

Example	Substrate	PU adhesive film	Peel force (N/m)	Failure mode
10	e-coated steel	PE393	13,414	Interfacial PU/steel
11	e-coated steel	PE399	24,902	Interfacial PU/steel
12	e-coated steel	A4700	20,944	Interfacial PU/steel
13	pretreated steel	A4700	2504	Interfacial PU/steel

#### EXAMPLES 14-15

[0073] Laminates of copolyestercarbonate-polycarbonate film assembly with e-coated aluminum and chemical conversion coated aluminum were prepared. E-coated aluminum test panels were obtained from ACT Laboratories (ACT # APR 41719). E-coated aluminum panels of the type used for automotive body panels had been cleaned, phosphate treated, and finally e-coated with PPG lead-free e-coating formulation (type ED6100H). Pretreated aluminum panels (cleaned and chemical conversion pretreated using Henkel immersion phosphate) were also obtained from ACT Laboratories (ACT # APR 41718). Laminates were prepared according to Examples 10-13 (except as noted) with copolyestercarbonate-polycarbonate film assembly onto an aluminum substrate using the PU film adhesive DUREFLEX A4700 of 0.6 mm thickness. The adhesion results are summarized in Table 6. In each

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example the adhesion strength of the copolyestercarbonate-polycarbonate film assembly to the metal substrate was found to be excellent.

TABLE 6

Example	Substrate	Molding temp. (°C)	Mold press. (kPa)	Peel force (N/m)	Failure mode
14	e-coated Al	121	172	26,180	Interfacial PU/Al & PU/PC
15	pretreated Al	127	689	7968	Interfacial PU/Al

#### ADHESION ENVIRONMENTAL STABILITY TESTS

[0074] Adhesion environmental stability data were determined for laminates of copolyestercarbonate-polycarbonate film assembly onto e-coated steel and SMC. Multilayer structures of copolyestercarbonate-polycarbonate film assembly over e-coated steel or SMC or e-coated aluminum, the same as those in examples 1-2 and 10-12, examples 6-7, and example 14, respectively, were prepared and subjected to a full cycle crack resistance test under varying conditions of temperature and humidity. Each full cycle involved holding the sample successively for 24 hours at 84°C, 16 hours at 38°C and 98% relative humidity, 6 hours at minus 29°C, and 2 hours at 23°C. Each sample was subjected to 15 cycles. All samples were visually inspected after the full cycle crack test and were found to have no macroscopic delamination or other film-related failure. These 10.2 cm by 15.2 cm cycle cracked samples were then cut into 2.54 cm by 15.2 cm test specimen for 90-degree peel test at 2.54 cm per minute cross-head separation speed. The results are summarized in Table 7.

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TABLE 7

Example	Substrate	Adhesive/ Thickness of adhesive	Peel strength after cycle crack test (N/m)	Peel failure mode
1	e-coated steel	ARALDITE 2040 0.13 mm	5779	Cohesive PU and interfacial PC/PU
2	e-coated steel	ARALDITE 2042 0.13 mm	175 - 525	Interfacial PC/PU
6	SMC	ARALDITE 2040 0.5 mm	3520	Interfacial PC/PU
7	SMC	ARALDITE 2042 0.5 mm	350	Interfacial SMC/PU
10	e-coated steel	PE393 1.3 mm film	17,845	---
11	e-coated steel	PE399 1.3 mm film	21,102	---
12	e-coated steel	A4700 1.3 mm film	28,387	---
14	e-coated Al	A4700 0.6 mm film	24,201	---

[0075] The results showed that adhesion provided to copolyestercarbonate-polycarbonate film assembly and e-coated steel by ARALDITE 2040 and the three types of polyurethane film is environmentally stable, and adhesion strength remains excellent after the full cycle crack test protocol. Although the invention is not dependent upon any theory of action, this excellent adhesion stability may be due to the hydrolytic stability and/or low modulus of ARALDITE 2040 and of the three types of polyurethane film which allows them to accommodate any CTE mismatch between copolyestercarbonate-polycarbonate film assembly and low CTE substrates.

#### EXAMPLE 16

[0076] In-mold decoration was performed. A block copolymer (sometimes designated hereinafter as "TU") comprising a thermoplastic polyurethane (PU) block

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and a hydrogenated styrene block copolymer (HSBC) block, TU S5865, was obtained from Kuraray Corporation. A 0.25 mm x 8.9 cm x 10.2 cm bisphenol A polycarbonate film was placed in a 0.5 cm x 10.2 cm x 10.2 cm plaque mold. TU S5865 copolymer was injection molded behind the polycarbonate film. The polycarbonate film was found to adhere well to the TU copolymer. The 90-degree peel force was found to be about 10,157 Newtons per linear meter; the film was torn during the peel test.

#### EXAMPLE 17

[0077] In-mold decoration was performed. A blend ("AU50") was made by blending 100 parts of TU S5865 with 100 parts of SEPTON 8006, 100 parts of paraffinic oil, 200 parts of a thermoplastic polyurethane elastomer (KURAMIRON 8165, obtained from Kuraray Corporation), and minor amounts of hindered phenolic heat stabilizers and slipping agent montanic ester wax. A 0.25 mm x 8.9 cm x 10.2 cm bisphenol A polycarbonate film was placed in a 0.5 cm x 10.2 cm x 10.2 cm plaque mold. AU50 blend was injection molded behind the polycarbonate film. The polycarbonate film was found to adhere well to the AU50 blend. The 90-degree peel force was found to be about 9456 Newtons per linear meter; the failure mode was tearing of AU50.

#### EXAMPLE 18

[0078] In-mold decoration was performed. A blend ("AU60") was made by blending 100 parts of TU S5865 with 100 parts of SEPTON 8006, 100 parts of paraffinic oil, 200 parts of a thermoplastic polyurethane elastomer (KURAMIRON 9190, obtained from Kuraray Corporation), and minor amounts of hindered phenolic heat stabilizers and slipping agent montanic ester wax. AU60 blend was injection molded behind a 0.25 mm thick bisphenol A polycarbonate film. The polycarbonate film was found to adhere well to AU60 blend. The 90-degree peel force was found to be about 13,834 Newtons per linear meter; the polycarbonate film was torn during the peel test.

#### EXAMPLES 19-26

[0079] In-mold decoration was performed. In these examples Nylon 6 was obtained from Honeywell. All other resins were from GE Plastics. TU S5865 films of 0.16 cm

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x 10.2 cm x 15.2 cm in dimension were made by injection molding process. The film was placed in the cavity of a 0.5 cm x 10.2 cm x 10.2 cm plaque mold and thermoplastic resins, listed in Table 1, were injection molded behind the film to create in-mold decorated plaques with a TU S5865 resin layer and a substrate layer. The 90-degree peel strength was measured; data are listed in Table 8.

TABLE 8

Example	Material	Peel Strength (N/m)	Failure Mode
19	CYCOLAC GPM 5500	4150	Interfacial
20	CYCOLAC EPBM 3570	3782	Interfacial
21	CYCOLAC X37	4098	Interfacial
22	CYCOLOY MC8002	4168	Interfacial
23	GELOY 4034	3993	Interfacial
24	Nylon 6 (CAPRON 1250)	3415	Interfacial
25	GTX 902	2014	Interfacial
26	VALOX 315	1979	Interfacial

#### COMPARATIVE EXAMPLES 1-4

[0080] The following multilayer articles contained no tielayer. A 0.8 mm x 8.9 cm x 10.2 cm copolyestercarbonate-polycarbonate film assembly was placed in the cavity of a 0.5 cm x 10.2 cm x 10.2 cm plaque mold. Various resins were injection molded behind the polycarbonate film of the film assembly. The 90-degree peel strength was measured; data are listed in Table 9. The copolyestercarbonate-polycarbonate film assembly was found to adhere poorly to these substrates without using a tielayer.

TABLE 9

Comparative Examples	Material	Peel Strength (N/m)
C1	CYCOLAC EPBM 3570	<500
C2	CYCOLAC X37	<500
C3	CYCOLOY MC8002	2224
C4	GELOY XP4025	<500

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#### EXAMPLES 27-34

[0081] In-mold decoration was performed. AU50, a blend of TU polymer as described in Example 17, was made into films of 0.16 cm x 10.2 cm x 15.2 cm dimensions by an injection molding process. Since AU50 is a relative soft material and will tear if there is significant adhesion, a 1.8 mm bisphenol A polycarbonate film was laminated with the AU50 film before it was inserted into the mold. The film assembly was placed in the cavity of a 0.5 cm x 10.2 cm x 10.2 cm plaque mold and thermoplastic resins were injection molded behind the AU50 film of the film assembly to create an in-mold decorated plaque. The 90-degree peel strength was tested; data are listed in Table 10. In most cases, the failure mode was cohesive AU50 tielayer failure.

TABLE 10

Example	Material	Peel Strength (N/m)	Failure Mode
27	CYCOLAC GPM 5500	5901	Cohesive
28	CYCOLAC EPBM 3570	5621	Cohesive
29	CYCOLAC X37	4588	Cohesive
30	CYCOLOY MC8002	5096	Cohesive
31	GELOY 4034	4781	Cohesive
32	Nylon 6	4676	Cohesive
33	GTX 902	5166	Cohesive
34	VALOX 315	1979	Interfacial

#### EXAMPLES 35-42

[0082] In-mold decoration was performed. AU60, a blend of TU polymer as described in Example 18, was made into films of 0.16 cm x 10.2 cm x 15.2 cm dimensions by an injection molding process. The film was placed in the cavity of a 0.5 cm x 10.2 cm x 10.2 cm plaque mold and thermoplastic resins were injection molded behind it to create an in-mold decorated plaque of such film with a substrate layer. The 90-degree peel strength was tested; data are listed in Table 11.



TABLE 11

Example	Material	Peel Strength (N/m)	Failure Mode
35	CYCOLAC GPM 5500	5919	Cohesive/Interfacial
36	CYCOLAC EPBM 3570	5306	Cohesive/Interfacial
37	CYCOLAC X37	5901	Cohesive/Interfacial
38	CYCOLOY MC8002	5429	Cohesive/Interfacial
39	GELOY 4034	6059	Cohesive/Interfacial
40	Nylon 6	5341	Cohesive/Interfacial
41	GTX 902	2942	Interfacial
42	VALOX 315	2312	Interfacial

#### EXAMPLE 43

[0083] Extrusion coating and in-mold decoration were performed. A 0.25 mm thick AU50 layer was extrusion coated on the back of a 0.5 mm thick bisphenol A polycarbonate film at 216°C. The polycarbonate film with AU50 extrusion coated on the backside was then inserted in a 0.5 cm x 10.2 cm x 10.2 cm plaque mold, and CYCOLOY MC8002 resin was injection molded behind the AU50 film of the film assembly to make polycarbonate/AU50/CYCOLOY MC8002 multilayer articles. It was found that AU50 worked as an effective tie layer for polycarbonate adhesion to the CYCOLOY substrate. The peel strength was 5289 Newtons per linear meter and the failure mode was a combination of cohesive AU50 tielayer and interfacial failure.

#### EXAMPLE 44

[0084] Adhesion strength after cycle crack testing was determined. A film assembly of TU S5865 copolymer injection molded behind bisphenol A polycarbonate film as in example 16 was subjected to temperature and humidity cycling following the full cycle crack resistance test protocol described hereinabove. The peel strength after full cycle crack test protocol was found to be 9281 Newtons per linear meter.

#### EXAMPLE 45

[0085] Adhesion strength after cycle crack testing was determined. A film assembly of AU50 blend injection molded behind bisphenol A polycarbonate film as in example

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17 was subjected to temperature and humidity cycling following the full cycle crack resistance test protocol described hereinabove. The peel strength after full cycle crack test protocol was found to be 10,332 Newtons per linear meter; the failure mode was tearing of AU50.

#### EXAMPLE 46

[0086] Adhesion strength after cycle crack testing was determined. A film assembly of AU60 blend injection molded behind a bisphenol A polycarbonate film as in example 18 was subjected to temperature and humidity cycling following the full cycle crack resistance test protocol described hereinabove. The peel strength after full cycle crack test protocol was found to be nearly 15,760 Newtons per linear meter. Polycarbonate film was torn during peel test.

#### EXAMPLES 47-53

[0087] Adhesion strength after cycle crack testing was determined. Film assemblies of thermoplastic resins injection molded behind a TU S5865 resin layer prepared in the same manner as in examples 19-26 were subjected to temperature and humidity cycling following the full cycle crack resistance test protocol described hereinabove. The peel strength data after full cycle crack test protocol are listed in Table 12.

TABLE 12

Example	Material	Peel Strength (N/m)	Failure Mode
47	CYCOLAC GPM 5500	3625	Interfacial
48	CYCOLAC EPBM 3570	2995	Interfacial
49	CYCOLAC X37	3222	Interfacial
50	CYCOLOY MC8002	3607	Interfacial
51	GELLOY 4034	3537	Interfacial
52	GTX 902	1331	Interfacial
53	VALOX 315	946	Interfacial

#### EXAMPLES 54-60

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[0088] Adhesion strength after cycle crack testing was determined. Film assemblies of thermoplastic resins injection molded behind a AU50 blend layer prepared in the same manner as in examples 27-34 were subjected to temperature and humidity cycling following the full cycle crack resistance test protocol described hereinabove. The peel strength data after full cycle crack test protocol are listed in Table 13.

TABLE 13

Example	Material	Peel Strength (N/m)	Failure Mode
54	CYCOLAC GPM 5500	5534	Cohesive
55	CYCOLAC EPBM 3570	5131	Cohesive
56	CYCOLAC X37	5113	Cohesive
57	CYCOLOY MC8002	4693	Cohesive
58	GELOY 4034	4711	Cohesive
59	GTX 902	5849	Cohesive
60	VALOX 315	1664	Interfacial

#### EXAMPLES 61-63

[0089] Laminates of polypropylene (PP) or bisphenol A polycarbonate (PC) onto a layer comprising a blend of a polyurethane-comprising adhesive with a resinous copolymer were prepared by an in-mold decoration process. ESCORENE PP8224 comprising polypropylene structural units was obtained from ExxonMobil. OREVAC SPP SM7, a chemically functionalized syndiotactic polypropylene (PP) with a medium content of maleic anhydride (0.4% by weight) was obtained from AtoFina. HYBRAR H7125 (referred to hereinafter as HYBRAR), obtained from Kuraray Co., was a hydrogenated block copolymer comprising polystyrene end blocks and a vinyl bonded, polyisoprene-rich middle block. A block copolymer comprising a thermoplastic polyurethane block and a hydrogenated styrene-diene block was obtained from Kuraray Corporation under the designation TU S5865. A blend of 30 wt.% of TU S5865 and 70 wt.% of HYBRAR 7125 was extruded. Films (1.6 mm x 10.2 cm x 15.2 cm) of such blend were made by an injection molding process. The film was placed in the cavity of a mold and PP or PC substrate was injection molded behind the film. The film was found to adhere well to the substrates. Since the adhesion strength was found to exceed the elongation strength of the peel arm, an

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adhesive tape backing was used during the peel test. The 90-degree peel strength values are listed in Table 14. The adhesion strength was very high. No delamination was observed in examples 61-62 and partial delamination was observed in example 63.

TABLE 14

Example	Material	Peel Strength (N/m)	Failure mode
61	AtoFina PP	5692	Peel arm stretch, no delamination
62	ESCORENE PP	5481	Peel arm stretch, no delamination
63	PC	4746	Peel arm stretch, partial delamination

#### ADHESION ENVIRONMENTAL STABILITY TESTS

[0090] Adhesion environmental stability data were determined for laminates prepared as in Example 61-63 and subjected to a full cycle crack resistance test under varying conditions of temperature and humidity as those in Table 7. The treated samples were then cut into 2.54 cm by 15.2 cm test specimens for 90-degree peel test at 2.54 cm per minute crosshead separation speed. Since the adhesion strength exceeded the elongation strength of the peel arm, an adhesive tape backing was used during the peel test. The measured peel strength values are listed in Table 15. The results showed that the HYBRAR blend adhesion to PP and PC film is environmentally stable, as adhesion strength remains excellent after the full cycle crack test protocol. No delamination was observed during the peel test in examples 61-62 and partial delamination was observed in example 63.

TABLE 15

Examples	Material	Peel Strength (N/m)	Failure mode
61	AtoFina PP	4746	Peel arm stretch, no delamination

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62	ESCORENE PP	5411	Peel arm stretch, no delamination
63	PC	4956	Peel arm stretch, partial delamination

#### EXAMPLES 64-71

[0091] Multilayer articles were prepared comprising polycarbonate (PC) film over long fiber injection polyurethane (LFI-PU) foam. TPU films (grades UAF and TAF) were obtained from Adhesive Films Inc., Pine Brook, New Jersey; Bemis TPU film (grade 3410) was obtained from Bemis Company, Minneapolis, Minnesota. The PC film and adhesive layers were laminated using a roll laminator to form an assembly. The lamination of adhesive film and PC occurred at a nip point. The heat needed for lamination was either supplied by the heated rolls or by preheating the surfaces using infrared radiation. Molding experiments were conducted to evaluate the adhesion of several tielayers to both high-density (HD) and low-density (LD) PU foams. In all cases the PC-tielayer assembly was placed in a mold cavity. Liquid streams comprising isocyanate and polyol were metered at high pressure through a mixing head and fed into the mold cavity along with chopped glass strands. All the PU foam formulations contained chopped glass (about 25 mm average length) and an internal mold release agent. An exothermic reaction inside the mold results in curing of the PU foam. Addition of water to the formulation results in evolution of carbon dioxide gas and foamed product. As summarized in Table 16, a variety of TPU films provided excellent adhesion for PC film to cured PU foam, with the 90 degree peel strength value well above the value typically needed for automotive applications. In most cases, the peel failure mode was cohesive failure of PU foam substrates.

TABLE 16

Example	Tie Layer	LFI-PU foam type	As-molded Peel Strength (N/m)	Failure Mode
64	UAF 420	HD	23,642	Cohesive substrate and interfacial tie/substrate
65	Bemis 3410	HD	19,089	Cohesive substrate and film tear
66	UAF 440	HD	10,858	Cohesive substrate and interfacial tie/substrate
67	UAF 430	LD	6917	Cohesive substrate

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68	TAF 850	LD	6515	Cohesive substrate
69	UAF 420	LD	4711	Cohesive substrate
70	TAF 880	LD	4676	Cohesive substrate
71	TAF 850	LD	4378	Cohesive substrate

#### EXAMPLE 72-79

**[0092]** Adhesion Environmental Stability Tests were performed. LFI-PU multilayer structures were prepared as in Example 64-71 and subjected to a full cycle crack resistance test under varying conditions of temperature and humidity as described hereinabove. All samples were visually inspected after the full cycle crack test and were found to have no macroscopic delamination or other film-related failure. The treated samples were then cut into 2.5 cm by 20 cm test specimens for 90 degree peel test at 2.5 cm per minute crosshead separation speed. The measured peel strength values are listed in Table 17. The results showed that adhesion provided to PC film over LFI-PU foam by the TPU tielayers is environmentally stable, as adhesion strength remains excellent after the full cycle crack resistance test protocol.

TABLE 17

Example	Tie Layer	LFI-PU foam type	Peel Strength After Cycle Crack Test (N/m)
72	UAF 420	HD	16,175
73	Bemis 3410	HD	9299
74	UAF 440	HD	2930
75	UAF 430	LD	7177
76	TAF 850	LD	6397
77	UAF 420	LD	4594
78	TAF 880	LD	6958
79	TAF 850	LD	7119

#### COMPARATIVE EXAMPLE 5

**[0093]** Multilayer articles comprising a polycarbonate film and either HD- or LD-LFI-PU substrate were prepared in the same manner as those in Examples 64-71 except that no tielayer was used. The polycarbonate film was found to have poor adhesion to

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either PU foam and delamination occurred in molded parts. A 90 degree peel test showed that the polycarbonate film adhesion to the PU foam was only about 350 N/m.

**[0094]** While the invention has been illustrated and described in typical embodiments, it is not intended to be limited to the details shown, since various modifications and substitutions can be made without departing in any way from the spirit of the present invention. As such, further modifications and equivalents of the invention herein disclosed may occur to persons skilled in the art using no more than routine experimentation, and all such modifications and equivalents are believed to be within the spirit and scope of the invention as defined by the following claims. All Patents, patent applications and published articles cited herein are incorporated herein by reference.